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Mechanical and Chemical Release Applied to a 16-Year-Old Pine Plantation

Gary O. Fiddler, Philip M. McDonald,
and Sylvia R. Mori

Plantation establishment in California is often a difficult task. Earlier studies reported that almost all new plantations in the state will be invaded by vegetation in the form of hardwoods, woody shrubs, grasses, and forbs.¹ The competition between this vegetation and the planted conifers is almost always detrimental to the growth and survival of the conifers.^{2,3} To further complicate matters, this invasion of weedy species usually occurs early in the life of the plantation, at which time the planted conifers are establishing growth patterns that will be followed at least until crown closure. Growth patterns of conifers in plantations under competition are less than can be expected from conifers growing in released plantations. Once lost, this growth is never recovered.³ In order for the conifers to develop at or near the potential of the site, they must be released from competing vegetation early in the life of the plantation, probably the first or second year after planting.^{4,5,6}

Despite the need for release, untreated conifer plantations 10 years or older are common in the western U.S., especially on Federal lands. Ponderosa pine (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*) and Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) have demonstrated their ability to survive despite extreme competition, but this competition results in decreased growth of the planted conifers. The fact that pine seedlings are taller than the surrounding vegetation does not guarantee that they will grow at the potential of the site. This height does not mean rapid or even moderate growth. Will these older plantations respond to a release treatment, and if so, what treatment will be best?

Controlling vegetation of the size and level of development found in older plantations is difficult to accomplish by using commonly applied methods. Because of large shrubs and the difficulty of disposing of the cut material, limited crew access makes manual methods prohibitively expensive when used with older vegetation. The cut material generated with the manual methods must be disposed of to avoid creating unacceptable residual slash levels that contribute to the fire hazard in the treated areas. Grazing by cattle or sheep is, at best, marginally effective.⁷ Controlling tall, well-developed shrubs is often ineffective, even when using herbicides alone.

To accomplish release in older plantations having large, tall shrubs, Federal land managers often choose mechanical means as the most appropriate release method. This method involves the use of a mechanical cutter, similar to a lawn mower, which cuts the competing vegetation close to the ground and leaves the chopped stems and foliage on site. However, does this operation reduce the competing vegetation long enough to increase the growth of the conifer saplings? Results from an earlier study indicated that it does not, but that sprouts grew rapidly from the treated vegetation.⁸

This paper discusses the effectiveness of mechanical cutting as a release method in an older pine plantation; the effectiveness of applying an herbicide to

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To increase the growth of planted conifer saplings, the competing vegetation in a 16-year-old pine plantation on the Plumas National Forest in northern California was mechanically treated with the Trac-mac mechanical cutter. The large size of this vegetation (chinkapin, greenleaf manzanita, whitethorn, huckleberry oak) eliminated other release methods as feasible alternatives. Additional treatments were a chemical treatment, in which 2,4-D was applied to a portion of the study site that had been treated with the Trac-mac 2 years previously, and untreated control. Eleven growing seasons after treatment, mechanical release alone did not significantly increase diameter, height, or crown cover of the pines compared to the control. In contrast, the Trac-mac plus herbicide (chemical) treatment statistically increased conifer crown cover compared to the other two treatments. Pine diameter and height were also larger in the chemical treatment than in the other two treatments, but not

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the mechanically cut shrubs 2 years after cutting; the cost and production of all treatments; and the pine growth response in diameter, height, and crown cover to the treatments and an untreated control, as well as responses of the treated and untreated shrub community.

Methods

The study site, known as Third Water, is located on the Quincy Ranger District of the Plumas National Forest in northeastern California. The site is about 90 air miles southeast of Redding, California. The study is part of a national administrative study on vegetation management in young conifer plantations started in 1980 in northern California.⁹ Before timber harvest, the study site supported a forest of ponderosa pine, California white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.), incense cedar (*Libocedrus decurrens* Torr.), and sugar pine (*Pinus lambertiana* Dougl.). The understory consisted of small amounts of greenleaf manzanita (*Arctostaphylos patula* Greene), mountain whitethorn (*Ceanothus cordulatus* Kell.), and Sierra chinkapin (*Castanopsis sempervirens* [Kell.] Dudl.). A few scattered *Prunus* species and small numbers of grasses and forbs were also present.

The site was harvested in 1964 or early 1965. Site preparation was done in July 1965; a crawler tractor was used to crush the shrubs in preparation for burning. The tractor, with the blade about 1 foot above the ground, made two passes in opposite directions, which resulted in a fuel arrangement less than 2 feet high. Large snags and large downed woody debris were removed before burning. The site was broadcast burned in fall 1965 and spring 1966. Ponderosa pine and Jeffrey pine seedlings from a local seed source were raised at the USDA Forest Service nursery at Placerville, California, and hand planted as 1-year-old, bare-root stock in spring 1966. About 300 trees per acre were planted. Survival at the time the study began, September 1982, was between 140 and 240 planted trees per acre.

In fall 1982, 17 years after site preparation, the area supported, in addition to the planted conifers, a dense cover of greenleaf manzanita, mountain whitethorn, Sierra chinkapin, and huckleberry oak (*Quercus vaccinifolia* Kellogg) as sprouts from plants in the previous stand and new seedlings. Height of these shrubs ranged from 2 to 4 feet. The most common shrubs were greenleaf manzanita and whitethorn, which totalled about 35,000 plants per acre. Grass, mostly from the genera *Bromus* and *Stipa*, was present in small numbers on the site.

Elevation of the study site is 5,500 feet with slopes of 5 to 15 percent and aspects of northwest and south. The climate is characterized by warm, dry summers and cold, moist winters. Mean annual precipitation is about 70 inches with 50 to 60 percent falling as snow. The mean January temperature is 38°F, mean July temperature is 65°F, and the mean annual temperature is 52°F. The frost-free season is from early May until mid-October.

The soil is of the Gibsonville family, which is found on ridge tops and side slopes. It is moderately deep, well drained, and formed from weathered volcanic material. The soil is sandy loam and may be gravelly or cobbly.

On the basis of the height-age relationship of dominant mixed conifer trees, site quality of the study area before harvesting was 65 feet in 50 years.¹⁰ Slope and site quality are very uniform throughout the study area.

Evidence of deer (*Hemionus* spp.) was common throughout the study area. Small rodents and birds were seen. Pocket gophers (*Thomomys* spp.) were noticed in the area.

The study, which began in fall 1981, includes data recorded through 10 growing seasons. The experimental design was a complete randomized block with one three-level treatment. Differences among treatments were detected by analysis of variance of treatment means¹¹ and Tukey tests.¹² Statistical significance in all tests was at $\alpha = 0.05$. Because information is gathered from permanent plots

(continued from page 1)
significantly. Mean crown cover was 120 percent greater in the saplings in the chemical treatment than for pines in the control, height was 35 percent greater, and diameter was 50 percent greater. Relative costs were \$218 per acre for the mechanical treatment and \$267 per acre for the Trac-mac plus herbicide (chemical). The most cost-effective treatment was Trac-mac plus herbicide.

Retrieval Terms: competing vegetation, cost, growth, mechanical release, mechanical and chemical release, Jeffrey pine, ponderosa pine, shrub sprouts

measured each year, the data are not truly independent from year to year. The α levels or type I errors apply to each measurement and year separately. The overall error rate could increase by as much as the given amount for each measured variable each year. S-Plus 2000¹³ by Mathsoft, Inc. was used for graphic displays and exploratory analysis.

Treatments, each replicated three times (three blocks), included mechanical, chemical (mechanical plus an herbicide), and a control. A replicate consisted of about one-seventh of an acre with 30 to 40 ponderosa or Jeffrey pine saplings surrounded by two or three rows of buffer (saplings receiving the same treatment). Twenty of these pines per replication were chosen for measurement of height, stem diameter at 4.5 feet above mean ground line, and crown cover. Those chosen were thrifty saplings that had good potential of becoming harvestable trees; small, misshapen, and discolored saplings were not part of the study.

Sampling intensity for evaluating competing vegetation consisted of nine randomly selected plots in each replication. Plots were centered around conifers and were 1 milacre (0.001) in size. Vegetation was evaluated for density, foliar cover (the sum of shadows that would be cast by leaves and stems of individual species expressed as percentage of the land surface),¹⁴ and average dominant height (average of the three tallest stems measured from mean ground line to bud). More specifically, number of plants in each subplot was counted, foliar cover was visually estimated, and height was measured with a graduated pole. Cover values of less than 0.5 square foot per species in each plot were not recorded. The most common species—chinkapin, greenleaf manzanita, whitethorn, and huckleberry oak—were analyzed separately. In addition, after combining these four species with the other shrubs in the study, a separate analysis was made using this grouping.

To quantify plant diversity, all species were noted on study plots when the study began and when it ended.

Mechanical treatment consisted of cutting the woody shrubs with a Trac-mac¹⁵—a machine with a large rotary cutting head that has three free-swinging blades. The cutting head is mounted on an all-terrain, tracked vehicle similar in size to a medium-sized log skidder. The Trac-mac resembles a common rotary lawnmower, but cuts a 4-foot swath. With experienced operators, as in this study, the Trac-mac works efficiently on slopes up to about 40 percent. Production rates of 3 to 4 acres per day are common. Current (1998) bids for this type of equipment on Forest Service contracts are about \$200 per acre. Severed material remains in place. Cutting was done in summer 1981.

Chemical treatment consisted of applying 3 pounds acid equivalent of 2,4-D¹⁶ in 10 gallons of solution per acre to the foliage of sprouting shrubs the second year after cutting. The herbicide was applied in August 1983 by using a carbon dioxide pressurized boom. Nozzles on the boom were the same type as those used in helicopter application; hence, rate of application and droplet size were similar to those used in aerial application of herbicides. The boom, which covered a 9-foot swath, was held about 12 inches above the shrubs, and the spray was directed downward. The system was calibrated by using trial runs with water to determine the proper walking speed to apply the correct amount of herbicide to each replication. The entire seventh-acre replicate, plus half of the buffer width, was sprayed. The area treated around each pine had at least a 5-foot radius. Workers guided the applicator at each side of the swath to ensure even coverage and no overlap.

A control served to show the response of naturally developing vegetation and its effects on the planted conifers.

Production data were gathered for each treatment. The basis for production was hourly records; the basis for costs was \$87.20 per hour (the 1998 rate for equipment of the type used in the study) and \$11.39 per hour (the rate for a Laborer-1, U.S. Department of Labor, as of June 1997).

Results

Data on survival, stem diameter, height, and crown cover are presented for the planted ponderosa and Jeffrey pine saplings, and information on density, foliar cover, and height for chinkapin, greenleaf manzanita, whitethorn, and huckleberry oak is reported. Because competition to the pine saplings results from the interaction of the different species found in the plant community, not from individual members of it, information is also presented for a grouping of shrubs called “combined shrubs.”

Ponderosa and Jeffrey Pine

No planted pine saplings died during the study (1982-1993), and no damage to the planted conifers from the Trac-mac itself or from flying debris generated by the machine during the release operation was noted.

In 1988, the mature stands adjacent to the study site were attacked by the Douglas-fir tussock moth (*Orgyia pseudotsugata*). Many of the trees, especially the California white fir, in these stands were killed by the infestation. Numerous cocoons were attached to the branches of the trees. Little if any damage was noted to the saplings in the study area. This infestation had collapsed by the time of the next measurement period in 1992.

Differences among treatments in ponderosa pine crown cover and height were evident in 1984, the first growing season after initial treatment (fig. 1). A Tukey test showed that by the end of 1988, cover of the pines was significantly larger in the chemical treatment than in the control (table 1). By the end of the study in 1992, pine cover in the chemical treatment was significantly larger than pine cover in the other two treatments. Pine diameter and height never differed significantly among treatments during the life of the study.

Chinkapin

The evergreen shrub chinkapin was the third most abundant vegetation in the study, outnumbered by greenleaf manzanita and whitethorn (table 2). In 1982, density averaged 4,733 plants per acre in the control. Density peaked in 1984 at 5,267 plants per acre. By the end of the study in 1992, density was reduced to 3,600 plants per acre, a decrease of 24 percent. Cover in the control started at 933 ft²/acre in 1982, increased to 1,067 ft²/acre in 1984, and declined to 200 ft²/acre by the end of the study. This was a 79 percent decline. Height in the control increased from more than 2 feet in 1982 to almost 3 feet by 1992, which is an increase of 36 percent.

By the end of the 1992 growing season, the height of chinkapin in the chemical treatment was significantly shorter—1.75 feet—than the height of the chinkapin in the control—2.77 feet (table 3). There were never any significant differences among treatments in density or foliar cover during the study.

Greenleaf Manzanita

The fast-growing evergreen shrub greenleaf manzanita was the most abundant woody species at the start of the study and remained in this dominant position throughout the life of the study. In 1982, density averaged 23,333 plants per acre in the control (table 2). Density peaked at 23,467 plants per acre in 1984 and declined to 15,000 plants per acre by the end of the study in 1992. This represented a decline of 36 percent. Foliar cover started at 24,333 ft²/acre, increased to 32,133 ft²/acre in 1986, and then declined in 1992 to almost the same amount as at the start of the study. Foliar cover showed only a slight decline (1 percent) during the study period. Height started at 3.71 feet and increased steadily throughout the study, reaching 5.34 feet by the end of 1992. This was an increase of 31 percent. Greenleaf manzanita was by far the tallest woody shrub in the control.

By the end of the study in 1992, foliar cover in the chemical treatment amounted to 67 ft²/acre, which was significantly smaller than the 24,067 ft²/acre

in the control (table 3). Height in both the chemical treatment and the mechanical treatments—2.04 and 3.31 feet, respectively—was significantly shorter than the average height in the control—5.34 feet. Density never differed significantly among treatments during the study.

Whitethorn

In fall 1982, density of whitethorn plants in the control was 11,600 plants per acre with 7,667 ft²/acre of foliar cover and 2.09 feet of height (table 2). By the end of the study in the fall of 1992, density had decreased by 57 percent to 4,933 plants per acre, foliar cover had decreased by 76 percent to 1,867 ft²/acre, but height had increased by 11 percent to 2.31 feet. Although the whitethorn was the second most abundant shrub on the plots at the beginning of the study, this species was

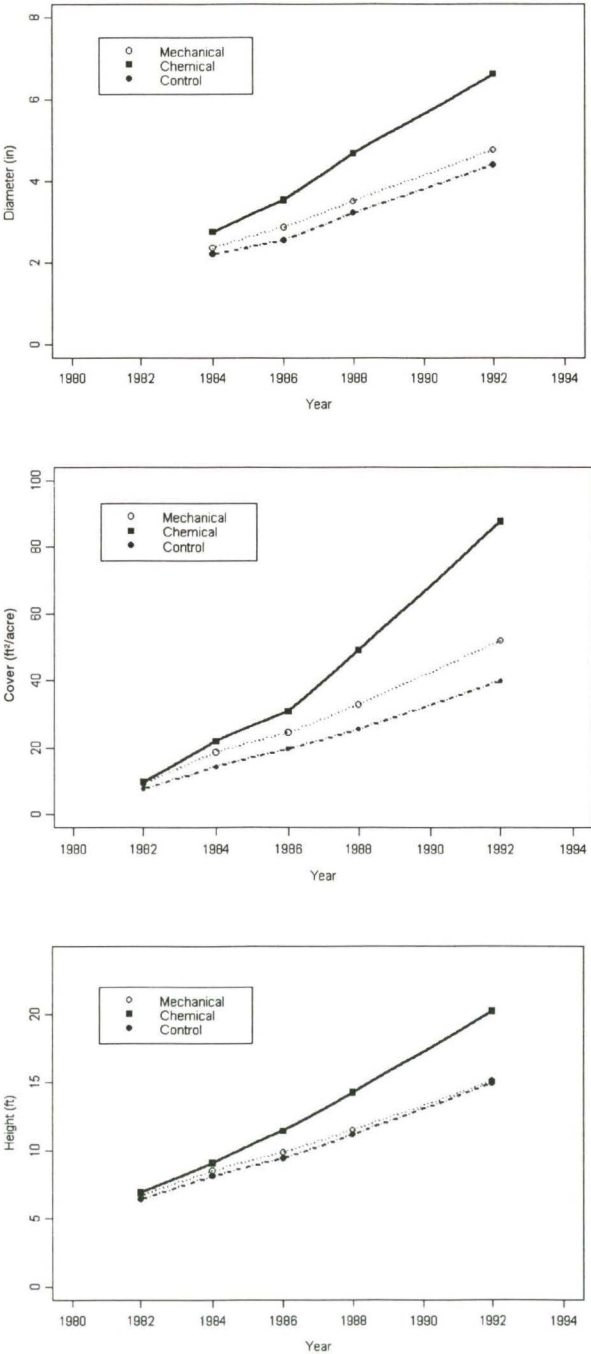


Figure 1
Average diameter, crown cover, and height of ponderosa and Jeffrey pine in treated (mechanical and chemical) and control plots, Third Water plantation, Plumas National Forest, California, 1982-1992.

Table 1—Average diameter, crown cover, and height of ponderosa and Jeffrey pine in treated and control plots, Third Water plantation, Plumas National Forest, California, 1982-1992.

Year	Treatment	Diameter	Cover	Height
		inches	ft ² /tree	ft
1982	Mechanical	-	9.32 a ¹	6.67 a
	Chemical	-	9.75 a	6.88 a
	Control	-	7.70 a	6.40 a
	Standard error	-	0.88	0.27
1984	Mechanical	2.36 a	18.67 a	8.50 a
	Chemical	2.75 a	22.00 a	9.07 a
	Control	2.21 a	14.35 a	8.13 a
	Standard error	0.21	2.35	0.47
1986	Mechanical	2.87 a	24.44 a	9.87 a
	Chemical	3.54 a	30.68 a	11.45 a
	Control	2.56 a	19.68 a	9.44 a
	Standard error	0.27	3.43	1.06
1988	Mechanical	3.51 a	32.67 ab	11.49 a
	Chemical	4.68 a	49.03 b	14.24 a
	Control	3.22 a	25.43 a	11.16 a
	Standard error	0.36	4.42	0.86
1992	Mechanical	4.76 a	51.83 a	15.08 a
	Chemical	6.61 a	87.48 b	20.20 a
	Control	4.40 a	39.81 a	14.95 a
	Standard error	0.45	6.51	1.21

¹ For each year, treatment means in each column followed by the same letter do not differ significantly according to a Tukey test ($\alpha = 0.05$).

being crowded out and overtopped by the more aggressive greenleaf manzanita and chinkapin.

In the fall of 1992, height of whitethorn in the chemical treatment was significantly shorter than that in the control (*table 3*). Density and foliar cover did not differ significantly at the close of the study.

Huckleberry Oak

Huckleberry oak, the low and expansive evergreen shrub, was the least abundant woody species at the start of the study and remained in that position throughout the study. In 1982, average density was 3,933 plants per acre in the control (*table 2*). Density reached a maximum at 4,600 plants per acre in 1984 and then declined steadily to 3,000 plants per acre by the end of the study in fall 1992. This was a 24 percent decline during the study. Foliar cover was at 400 ft²/acre at the start of the study, increased to 800 ft²/acre in 1984, and then steadily declined to 133 ft²/acre in the fall of 1992. This represented a decline of 67 percent during the study. Height started at 1.33 feet in 1982 and steadily increased through the 1988 growing season, reaching a height of 1.85 feet. By the end of the study in 1992, height had declined from the 1988 high to 1.44 feet. Height increased by 8 percent during the study.

After 10 growing seasons, density, foliar cover, or height of huckleberry oak did not differ significantly among treatments (*table 3*).

Combined Shrubs

Competition to the conifer saplings results from the interaction of the different species found in the plant community, not from individual members of it. Data

Table 2—Density, cover, and height, with standard errors (SE), of chinkapin, greenleaf manzanita, whitethorn, huckleberry oak, and combined shrubs in the control, 1982-1992.

Species	Density	SE	Cover	SE	Height	SE
	plants/acre		ft ² /acre		ft	
Chinkapin						
1982	4,733	1,444	933	467	2.04	0.67
1984	5,267	1,881	1,067	677	1.83	0.32
1986	5,000	1,922	933	742	2.41	0.33
1988	4,067	1,671	733	437	2.83	0.39
1992	3,600	1,311	200	115	2.77	0.31
Change (pct) ¹	-24		-79		+36	
Greenleaf manzanita						
1982	23,333	7,565	24,333	6,533	3.71	0.16
1984	23,467	7,142	28,533	6,567	4.54	0.12
1986	23,067	6,982	32,133	7,880	4.89	0.10
1988	20,600	7,159	30,200	9,928	5.31	0.10
1992	15,000	6,401	24,067	9,145	5.34	0.38
Change (pct)	-36		-1		+31	
Whitethorn						
1982	11,600	4,588	7,667	3,830	2.09	0.22
1984	10,933	3,886	7,467	3,868	2.45	0.16
1986	10,333	3,349	7,467	4,001	2.73	0.16
1988	9,133	2,839	4,133	2,219	2.76	0.22
1992	4,933	1,940	1,867	961	2.31	0.13
Change (pct)	-57		-76		+11	
Huckleberry oak						
1982	3,933	3,078	400	200	1.33	0.13
1984	4,600	3,219	800	416	1.40	0.25
1986	4,333	2,963	400	231	1.76	0.11
1988	4,200	2,996	200	115	1.85	0.15
1992	3,000	2,610	133	133	1.44	0.24
Change (pct)	-24		-67		+8	
Combined shrubs						
1982	45,000	10,938	35,933	7,378	2.61	0.08
1984	46,800	11,343	41,467	9,405	2.87	0.07
1986	45,133	10,811	44,467	10,104	3.26	0.08
1988	40,000	9,880	37,933	11,338	3.66	0.11
1992	28,400	9,488	27,467	9,551	3.31	0.16
Change (pct)	-37		-24		+27	

¹ Difference between 1982 and 1992 values expressed as a percent increase or decrease.

on a combination of shrub species best shows this relationship. The density, foliar cover, and height of chinkapin, greenleaf manzanita, whitethorn, and huckleberry oak were combined with data from bitter cherry (*Prunus emarginata* [Dougl.] Walp.), coffeeberry (*Rhamnus purshiana* DC.), snowberry (*Symphoricarpos* spp.), silktassel (*Garrya fermentii* Torr.), and service-berry (*Amelanchier utahensis* Koehne) and presented as “combined shrubs.”

In fall 1982, combined shrubs in the control numbered 45,000 plants per acre, had 35,933 square feet of foliar cover, and were 2.61 feet tall (*table 2*). Density increased to 46,800 plants by the end of the 1984 growing season. It declined to 28,400 plants per acre by the end of the study in fall 1992, which is a decrease of 37 percent. Foliar cover continued to increase until the end of the 1986 growing season when it reached a value of 44,467 ft²/acre. After 1986, foliar cover declined until the end of the study, with 27,467 ft²/acre. This represented a decline of 24 percent during the study. Height started at 2.61 feet in 1982 and increased through the 1988 growing season when it reached 3.66 feet. By the end of the study, height had declined from its 1988 value to 3.31 feet. Throughout the study, height of combined shrubs had a 27 percent gain.

Table 3—Density, cover, and height of chinkapin, greenleaf manzanita, whitethorn, huckleberry oak, and combined shrubs in treated and control plots, Plumas National Forest, 1992.

Species and Treatment	Density	Cover	Height
	plants/acre	ft ² /acre	ft
Chinkapin			
Mechanical	3,200 a ¹	600 a	2.41 ab
Chemical	7,533 a	133 a	1.75 b
Control	3,600 a	200 a	2.77 a
Standard error	1,758	168	0.18
Greenleaf manzanita			
Mechanical	21,733 a	7,933 ab	3.31 b
Chemical	5,000 a	67 b	2.04 b
Control	15,000 a	24,067 a	5.34 a
Standard error	4,431	4,634	0.35
Whitethorn			
Mechanical	7,200 a	1,533 a	1.79 ab
Chemical	5,933 a	267 a	1.56 b
Control	4,933 a	1,867 a	2.31 a
Standard error	1,791	609	0.11
Huckleberry oak			
Mechanical	2,133 a	733 a	1.56 a
Chemical	1,400 a	200 a	1.60 a
Control	3,000 a	133 a	1.44 a
Standard error	1,440	438	0.12
Combined shrubs			
Mechanical	36,267 a	12,067 ab	2.31 b
Chemical	21,000 a	800 b	1.75 b
Control	28,400 a	27,467 a	3.31 a
Standard error	6,248	4,859	0.14

¹For each species and combination, treatment means in each column followed by the same letter do not differ statistically at the 0.05 level.

At the end of the study, foliar cover differed significantly between treatments (table 3). With a value of 800 ft²/acre combined shrubs in the chemical treatment were significantly smaller than those in the control (27,467 ft²/acre). Also, shrub height showed a noticeable difference. Heights in the chemical treatment and the mechanical treatment (1.75 and 2.31 feet, respectively) were significantly shorter than the shrub heights in the control (3.31 feet). Density did not differ among treatments at the end of the study.

Cost and Production

Cost data for the mechanical treatment came from daily inspection records that were kept by Quincy Ranger District personnel who inspected the service contract for the work. Production rates for the equipment used to apply the treatments to the competing vegetation came from District records. Cost and production data for herbicide application in the chemical treatment came from project records.

The cost and production data generated by this study, although based on rates for smaller areas, compared favorably with rates from contracts awarded on several National Forests in northern California for similar work. This similarity was not unexpected since both the contract work and this study shared comparable terrain, competing plant species, types of treatments, and worker motivation.

Cost and labor to apply the chemical made this treatment more expensive than the mechanical treatment:

Treatment	Production rate	Cost
	Hours/acre	Dollars/acre
Mechanical	2.5	218
Chemical	5.5	267

Dollars per acre are for labor, equipment time, and chemical; they do not include overhead costs. All costs are updated to the most current rates available for labor and equipment of the type used on the study.

Plant Diversity

At the beginning of the study in 1982, the plant community consisted of 10 shrubs, 8 forbs, planted ponderosa and Jeffrey pine, and 2 graminoids. After 11 years, the community consisted of the same species with the addition of one fern and another species of forb. Many of the forbs, grasses, and shrubs were few in number and finding them was difficult because of their small size. The planted conifers, greenleaf manzanita, whitethorn, and chinkapin dominated the plantation, to the detriment of other species.

Discussion and Conclusions

In order to survive and remain thrifty, most conifer plantations in northern California must be released at least once in their lifetime. Considering both economics of the operation and effectiveness of the treatment, early release, usually within the first couple of years after outplanting, is the best time for this treatment. Despite the best efforts of land managers, many plantations do not receive this release treatment in a timely manner and often are not released until they are 10 to 12 years old. The size and amount of woody shrubs and other competing vegetation in these older plantations greatly complicate the choice of a release method. Many of the more commonly used methods are not effective when applied under the conditions found in these older plantations. Manual methods are prohibitively expensive when trying to control competing vegetation of this size and are seldom effective in accomplishing the release objective. Grazing by cattle or sheep is usually not an option because most of the vegetation is not palatable, and the vegetation that is desirable to the grazing animals is so tall that it is out of reach. Herbicides alone are ineffective when trying to control older, well-developed competing vegetation. Some kind of mechanical treatment is usually chosen to accomplish the release in older plantations.

Eleven growing seasons after treatment, mechanical release applied to a 16-year-old pine plantation did not significantly increase diameter, height, or crown cover of the saplings compared to the control. The mechanical release treatment costs \$218 per acre. In a variation to the mechanical treatment, herbicide was applied to the treated vegetation 2 years after the initial cutting operation. The application of the herbicide, including the chemical and the labor to apply it, cost \$49.42 per acre. The cost of the chemical treatment was the cost of mechanically cutting the competing vegetation (\$218/acre) plus the cost of applying the herbicide (\$49) for a total of \$267 per acre. The added cost of the chemical application resulted in an increase in conifer diameter, height, and crown cover in the chemical treatment, when compared to the mechanical treatment and control. By 1992, conifer crown cover was significantly larger in the chemical treatment than in the other treatments, increasing by 69 percent compared to the mechanical treatment and 120 percent compared to the control. Conifer diameter and height were also larger in the chemical treatment than in the other two treatments, but not significantly. This difference in conifer height and diameter

values between the chemical treatment and the other two treatments expanded at an increasing rate (*fig. 1*). If this rate continues, statistically significant differences should occur in the near future in conifer height and diameter, as is already evident in cover. Diameter in the chemical treatment was 39 percent larger than in the mechanical treatment and 50 percent larger than in the control. Pine height was 34 percent greater in the chemical treatment than in the mechanical treatment and 35 percent greater than in the control.

At the Third Water plantation, mechanical release alone was not an effective nor a cost-efficient release method. This finding was probably a result of the fact that the mechanical treatment left the root systems of the treated plants intact, allowing for rapid sprouting and continued occupation of the site by the nonconifer species. The planted conifers survived in all three treatments for at least 11 years after treatment application, but those in the control were growing as well as those in the mechanical treatment. Therefore, the mechanical treatment did little for the benefit of the conifers. For this reason, land managers will need to decide if even the most successful treatment (the addition of herbicide to a mechanical release treatment) is worth the cost and effort, since only conifer crown cover was increased significantly. Whether this increased crown growth will result in adequate conifer growth depends on future needs of the products from this plantation. Early release in the first few years of the life of the plantation would have minimized this dilemma.

End Notes and References

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¹⁶This note neither recommends the herbicide uses reported nor implies that the herbicides have been registered by the appropriate agencies.

The Authors

Gary O. Fiddler and **Philip M. McDonald** are Silviculturist and Research Forester, respectively, with the Pacific Southwest Research Station's Western Forests Ecology and Silviculture Program, Silviculture Laboratory, 2400 Washington Avenue, Redding, CA 96001. **Sylvia R. Mori** is Mathematical Statistician with the Pacific Southwest Research Station, 800 Buchanan Street, Albany, CA 94710.

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